

***Haemopsis caeca* (Annelida: Hirudinea: Arhynchobdellida: Haemopidae), a new species of troglobitic leech from a chemoautotrophically based groundwater ecosystem in Romania**

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Abstract.—A new species of leech, *Haemopsis caeca*, is described from a unique chemoautotrophically based groundwater ecosystem, in southern Dobruja, Romania, containing thermomineral H₂S rich water. Fifty invertebrate species have been identified from the cave, 33 of which are endemic species. *Haemopsis caeca* is the second species in the genus recorded from Europe, and the other Palearctic Region is *H. sanguisuga*. *Haemopsis caeca*, a cave adapted species, was observed exhibiting macrophagous feeding on the earthworm, *Alolobophora* sp., an undescribed species.

The new species, *Haemopsis caeca*, belongs to the Order Arhynchobdellida Blanchard 1894; Family Haemopidae Richardson 1969, Sawyer 1986b. The genus *Haemopsis* Savigny 1822 contains nine recognized species of which eight are endemic to the Nearctic Region (Richardson 1969, Soos 1969, Klemm 1985, Sawyer 1986b, Davies 1991). The species are *H. caballeroi* (Richardson 1971), *H. grandis* (Verrill 1874), *H. kingi* Mathers 1954, *H. lateromaculata* Mathers 1963, *H. marmorata* (Say 1824), *H. plumbea* Moore 1912, *H. septagon* Sawyer & Shelley 1976, and *H. terrestris* (Forbes 1890). Until now, the type species, *H. sanguisuga* (Linnaeus 1758), has been the only species of *Haemopsis* reported to occur in the Palearctic Region (Mann 1961, Soos 1970). However, *H. sanguisuga* has been reported from the Sino-Japanese Region of the Amur River Basin, in eastern Siberia, (Lukin 1955).

The three genera of Arhynchobdellida re-

ported from Europe, *Hirudo* Linnaeus 1758; *Haemopsis* Savigny 1822; and *Limnatis* Moquin-Tandon 1826, are also present in Romania (Cristea & Manoleli 1977, Manoleli 1972, 1974, Ruckert 1985, Soos 1969). However, none of these genera has been reported specifically in caves. The Natural History Museum of Oradea, Romania contains three specimens of *H. sanguisuga*, which were collected in 1892 in the Western Carpathians (Apuseni Mountains). The label mentions "cave habitat" with no further details. Scriban & Autrum (1934) examined the three specimens and found five pairs of eyes, and they all resembled morphologically the classic description of the (type) species, *H. sanguisuga*.

Materials and Methods

Fifteen leeches were collected by hand from the shoreline or near shoreline (0-20 cm) of the sulfidic lake in Movile Cave,

southern Romania (location in Sarbu 1996, Sarbu & Kane 1995). Nine specimens were observed while alive in the field and laboratory. Leeches to be preserved were first anesthetized by adding 70% ethanol slowly to a small amount of water containing the specimens until they no longer responded to stimulation. They were then preserved in either 70% ethyl alcohol or fixed overnight in 10% formalin and later stored in 70% alcohol. All drawings were made using either a IOR-MC1 dissecting microscope or a Zeiss Stemi SV6 dissecting microscope.

Systematics

Family Haemopidae Richardson, 1969;
(Sawyer 1986b, revised)

Genus *Haemopsis* Savigny, 1822
Haemopsis caeca, new species

Type material.—Holotype, deposited in the Muzeul de Istorie Naturala Bucuresti (MINB-49.999), Bucharest, Romania, and 2 representative paratypes (MINB-50.000), (collected 15 Jun 1992, sulfidic lake in Movile Cave, collector Serban M. Sarbu). Three additional paratypes, United States National Museum (USNM 178821), deposited in the National Museum of Natural History, Division of Worms, Smithsonian Institution, Washington, D.C.), collected 18 Jun 1996, sulfidic lake in Movile Cave, collector Serban M. Sarbu; 1 specimen, collected 20 Dec 1991, same locality, collector and collection Serban M. Sarbu; and 9 Oct 1994; 18 Jun 1996, same locality, collector Serban M. Sarbu, five specimens in the collection of Donald J. Klemm.

Type locality.—Movile Cave, southern Dobrogea, Romania.

Diagnosis.—without body pigment and eyes; body firm and muscular; annuli VIIa3 and VIIIa1 not subdivided ventrally; 25 annuli from oral cavity to annulus XIa2 bearing the male gonopore. Gonopores separated by 4 ½ annuli; jaws absent or vestigial (agnathous), denticles (teeth) absent; entrance to mouth and lumen of pharynx not strongly reduced; pharynx with 12 internal

ridges; testisac 8–10 pairs (8 in holotype); anterior edge of prostate at XII; penis sheath long, extends back to annuli XIIa2; penis has knot in its proximal end; vagina shaped like a bagpipe, proximal portion is thin; vaginal duct connects to the vagina subapically; vaginal duct exhibits a bifid shape in profile view; anus small, not prominent; macrophagous feeding (predaceous carnivore and scavenger); aquatic to semi-aquatic (amphibious).

Description of Holotype (Fig. 1B–E)

External anatomy (Fig. 1A, B).—Body firm, muscular (living and preserved), size medium, never large, body elongate, slender; length 50–63 mm, body-width 5–6 mm, depth 2–3 mm, body smooth, very contractile; the central portion with parallel or nearly parallel margins, usually terete anteriorly, pigment absent. Epidermis, transparent, and lacking chromatophores. Live animals red-brownish due to visible vascularization of muscle tissue. Annuli VIIa3 and VIIIa1 slightly enlarged, and faintly subdivided or not divided at all; 25 distinct annuli from oral cavity to annulus XIa2, bearing male gonopore; male and female gonopores separated by 4 ½ annuli. Anterior rim of mouth lip-like; one paratype exhibited a slight “emarginate” of the prostomium (Fig. 1A) and slight pigmentation strictly limited to this “emarginate,” other paratypes mouth more lip-like. Eyes absent in living and preserved specimens. Segment annuli I = 1, II = 1, III = 1, IV = 2, V = 2, VI = 3, VII = 3, VIII = 4, IX–XXIII = 5, XXIV = 3, XXV = 2, XXVI = 1, XXVII = 2. Anus small, not prominent on segment XXVII with no post-anal annuli; caudal sucker circular (width 3–4 mm), broadly and centrally attached to posterior end of body; nephridiopores 17, located paramedially on posterior portion of b2 annulus from segment VIII to XXIV; body with 15 complete (five annulate) segments from IX to XXIV; male genital pore located on segment XIa2; female genital pore lo-

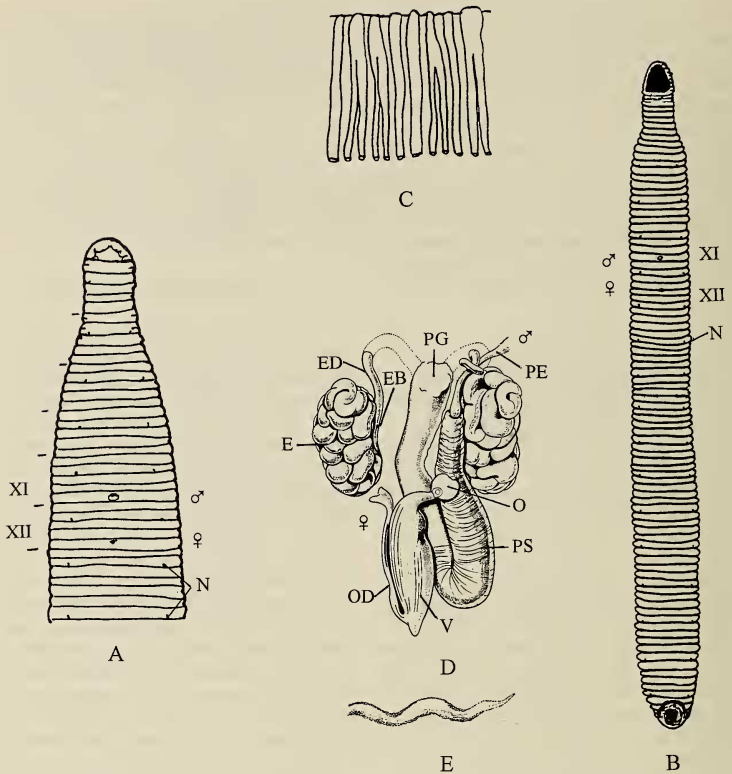


Fig. 1. *Haemopsis caeca*. A, Ventral view: Annuli VIIa3 and VIIIa1 not subdivided, 25 distinct annuli from oral cavity to segment XIa2, bearing the male gonopore; and male and female gonopores separated by $4\frac{1}{2}$ annuli; B, Ventral view of *Haemopsis caeca*; C, Pharynx, opened the mid-ventral line; D, Dorsal view of male and female reproduction systems; E, Distal end of the penis. Abbreviations: N, nephridiopore; Segments XI and XII; E, epididymis; EB, ejaculatory bulb; ED, ejaculatory duct; O, ovary; OD, oviduct; PG, prostate gland; PE, Penis; PS, penis sheath; V, vagina.

cated on segment XIIb2/a2; penis when fully extended, moderately long, small diameter (filamentous) proximal end, and distal end with a corkscrew-like tip (Fig. 1E).

Internal anatomy, male genitalia (Fig. 1D).—Epididymis occupying the space between the two genital pores; ejaculatory ducts short; sheath of penis extends back

reaching segment XIVb1; penis has a knot in its proximal end; testisacs 8–10 pairs. Female genitalia (Fig. 1D).—vagina has shape of a bagpipe; proximal portion of vagina is thin; vaginal oviduct connects to vagina subapically; proximal end of oviduct exhibits a bifid-shape in profile view. Digestive system.—pharynx euthylaematous, without

jaws (agnathous) and denticles, no salivary papillae; wall of pharynx intimately associated with muscles of body-wall; entrance to, and lumen of pharynx unrestricted with some 12 internal ridges, with four single ridges and four paired ridges, all terminating on the margin of the entrance to the pharynx (Fig. 1C); pharynx ending at X; crop tubular caecate, thin wall, elongate posterior crop caeca extending from XIX to XXIV; medium intestine, extending from XIX to XXIX; rectum, extending from XXIII to anus; anus small, not prominent.

Additional observations of paratypes.—The paratypes agree with the holotype externally and internally except for the “emarginate” of the prostomium (Fig. 1A) in a few specimens (this may be due to preservation); none of the specimens examined have eyes and all specimens have the same number of annuli between gonopores, 4 ½ annuli.

Remarks.—The structure of the reproductive system shows that this species belongs to the genus *Haemopsis*.

Habitat and ecology.—A unique chemoautotrophically based groundwater ecosystem was discovered in Movile Cave, at Mangalia, Dobrogea, Romania, near the Black Sea (Sarbu and Kane 1995). The cave was opened by an artificial shaft in 1986, and it represents a window to a vast network of fissures and cave passages of phreatic origin, associated with the thermomineral sulfidic waters present in the Mangalia region (Constantinescu 1989, Lascu 1989, Sarbu & Kane 1995). The lower level of the cave is flooded by mesothermal waters (21°C) with a high content of H₂S (0.3 mMol/L).

The cave contains rich aquatic and terrestrial troglobitic invertebrate communities (Lascu et al. 1993, Sarbu & Kane 1995). Thirty-three new invertebrate species, including *H. caeca*, have been discovered so far, and other discoveries are expected (Decu et al. 1994, Gruia et al. 1994, Weiss & Sarbu 1994). The food base of both the aquatic and terrestrial communities is pro-

duced *in situ* by a rich chemoautotrophic microbiota. These microbiota fix the carbon using the energy that results from the oxidation of H₂S at the surface of the water in the cave in aerobic conditions (Sarbu & Kane 1995). The Movile Cave ecosystem appears to be the first known subterranean ecosystem existing independently of the photoautotrophic carbon fixation in green plants at the surface. The cave ecosystem relies entirely on the *in situ* chemoautotrophically produced food base (Sarbu & Kane 1995, Sarbu et al. 1996).

Haemopsis caeca and another recently described endemic species, *Nepa anophthalma* (Decu et al. 1994), (Heteroptera: Nepidae), are the only known predators in the aquatic and semi-aquatic community and are thus far the largest animals found inhabiting the cave (Decu et al. 1994). Fifteen *H. caeca* have been observed above the shoreline displaying macrophagous feeding on earthworms (*Allolobophora* sp., an undescribed species). This aquatic and semi-aquatic leech was also observed in the cave creeping along the shores of the sulfidic lake. Specimens of the leech have often been seen swimming in the sulfidic lake, always in shallow water (0–15 cm deep).

Discussion

The genus *Haemopsis* was subdivided in North America by Richardson (1969, 1971) into three genera, *Percymoorensis*, *Mollibdella*, and *Bdellarogatis*. The revision was followed by Soos (1969) Davies (1971, 1991), and Klemm (1972). Sawyer (1972, 1986b, 1986c) and Sawyer & Shelley (1976) rejected this revision based on additional anatomical information and the description of a new species, *Haemopsis septagon* (Sawyer & Shelley 1976). Klemm (1977, 1982, 1985, 1990) later also followed their recommendations for the genus *Haemopsis*, which are followed by the authors of this paper.

The absence of eyes, body pigment, jaws, and denticles are four characteristics that

distinguish *H. caeca* from *H. sanguisuga*, the only other Palearctic Region species of the genus (Sawyer 1986b, Soos 1969). The anatomical examination of the two closely related Palearctic Region species reveals specific differences between *H. caeca*, the subterranean form, and the surface form of *H. sanguisuga*: the absence of eyes, epidermal chromatophores, jaws, and teeth; separation of the gonopores by 4 ½ annuli (*H. caeca*) rather than by 5–5 ½ annuli (*H. sanguisuga*). The male pore is located on XIa2 rather than XIb6, while the female pore is located on XIIb2/a2 rather than XIIb6. The body color of *H. caeca* is red-brownish dorsally and ventrally, but in *H. sanguisuga* the dorsal color varies from dark grey-green, to pale yellow-green, to almost black, and paler ventrally, with variable amounts of black flecking. The anus is small, less prominent in *H. caeca*, but is very conspicuous in *H. sanguisuga*. The examination of the paleogeographic data regarding the Mangalia region indicates that *H. caeca* may have been isolated underground for a considerable period of time, suggesting that the characteristics found in this stygobiotic species are genetically determined. All specimens of *H. caeca*, living and preserved, that have been examined thus far were found with eyes absent. All the other nine species of *Haemopsis*, including *H. sanguisuga*, have five pairs of eyes, and they have never been reported in the literature without eyes or variable number of eyes when collected and studied. All specimens of *H. caeca* examined internally were found with jaws and denticles absent. Seven species of *Haemopsis* possess low and rounded jaws with two distinct rows of large, course, blunt distichodont denticles, and the distichous denticles vary in numbers from 9–25. The other two Nearctic Region *Haemopsis* species, *H. grandis* (Verrill 1874) and *H. plumbea* Moore 1912, have vestigial or absent jaws and denticles. The total length of all *H. caeca* collected so far are also shorter (80–83 mm) and thinner (5–9 mm) than *H. sanguisuga*. The pharynx and related structures

are haemopisoid but are less prominent than in *H. sanguisuga*. Also, Segment VI and Segment VII have three annuli each in *H. caeca*, but in *H. sanguisuga* Segment VI has three annuli and Segment VII has four.

Turquin (1984) stated that several species belonging to the Order Arhynchobdellida and the Family Haemopidae may exhibit a certain degree of troglomorphy and can be found in dark places such as sewage systems where they seem to be attracted by the abundance of food such as aquatic worms and insect larvae. However, none of these troglomorphic invertebrate populations exhibit any morphological modifications compared to the populations living in surface waters. Agelek Cave in Hungary is inhabited by *Typhlobdella kavatsi* Deising 1850 (a junior synonym of *H. sanguisuga*), which exhibits all of the external characteristics found in *H. sanguisuga* (Lukin 1976, Soos 1969). Peck (1988) reported *H. terrestris* (Nearctic Region) from mines in Ontario, Canada. *Haemopsis terrestris* occurs in North America in two forms, either found living in freshwater or living in semi-aquatic to moist terrestrial habitats (Miller 1929, Klemm 1985, Sawyer 1986b).

In Erpobdellidae, a different family of leeches, Sawyer (1986a) reported that most troglomorphic leech species (e.g., *Trocheta bykowskii* Gedroyc (1915), of southeastern Europe), reported in caves and other subterranean habitats, are only migrants from outside the cave area and are indistinguishable from the surface-dwelling forms. However, Sawyer (1986a) stated that some truly cave-adapted aquatic erpobdellid species and closely related forms of uncertain taxonomic standing of *Dina lineata* (Muller 1774) live in caves in southern Europe and southwest Asia. For example, *D. absoloni* Johansson (1913), an unpigmented species, lives in caves of Yugoslavia and Bulgaria, and the subspecies, *D. absoloni ratschaensis* Kobakhidze (1958), lives in caves of western Georgian. Soos (1966) reported that a few truly unpigmented cave dwelling forms of *D. absoloni* have been reported

from Yugoslavia and Bulgaria with and without pigmented eyes and the integument unpigmented.

Haemopsis caeca, discovered in the Mobile Cave and collected later from a sulfidic spring in the same aquifer, about 4 km north of the cave, appears to be the only truly known cave-adapted species of *Haemopsis* (Family Haemopidae). The spring also contains other blind and unpigmented troglobitic animals, such as *Asellus aquaticus* (Isopoda: Asellidae); *Niphargus* sp., an undescribed species, and *Pontoniphargus racovitzai* (Amphipoda: Gammaridae). All of these species also are present in Mobile Cave.

Etymology.—From the Latin adjective *Caecus*, —a, —um meaning blind.

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Literature Cited

- Blanchard, R. 1894. Revision des Hirudinees du Musee de Dresde.—Abhandlungen und Berichte Zoologische Museum Dresden 1892-93, 4:1-8.
- Constantinescu, T. 1989. Considerations sur la zone karstique de "La Mobile" (Mangalia, Dobrogea du Sud, Roumanie).—Miscellanea Speologica Romanica 1:7-12.
- Cristea, V., & D. Manoleli. 1977. Conspectus des sangsues (Hirudinea) de Roumanie, avec une cle de determination.—Travaux Museum d'Histoire Naturelle "Grigore Antipa" 18:23-56.
- Davies, R. W. 1971. A key to the freshwater Hirudinoidea of Canada.—Journal Fishery Research Board Canada 28:543-552.
- . 1991. Annelida: Leeches, polychaetes, and acanthobdellids. Pp. 437-479 in J. H. Thorp & A. P. Covich, eds., Ecology and classification of North American freshwater invertebrates. Academic Press, Inc., San Diego, California.
- Decu, V., M. Gruia, S. L. Keffer, & S. M. Sarbu. 1994. Stygobiotic waterscorpion, *Nepa anophthalma* n. sp. (Heteroptera, Nepidae), from a sulfurous cave in Romania.—Annals Entomological Society of America 87:755-761.
- Diesing, C. M. 1850. Systema Helmintha, Vol. 1, Sect. 1: Vindobonae Mollia [In Latin], pp. 435-471. Reprinted by Hafner, New York (1960).
- Forbes, S. A. 1890. An American terrestrial leech.—American Naturalist 24:646-649.
- Gedroyc, M. 1915. Pijawki (Hirudinea) Polski. Studium monograficzne.—Rozprawy i Wiadomosci z Muzeum imienia Dzieduszychich Lwow 1(3-4):176-190.
- Gruia, M., V. Iavorschi, & S. M. Sarbu. 1994. *Armadillidium tabcarui* (Isopoda, Oniscidea, Armadillidiidae), a new troglobitic species from a sulfurous cave in Romania.—Proceedings of the Biological Society of Washington 107:699-706.
- Johansson, L. 1913. Uber eine neu von Dr. K. Absolon in der Herzegowina entdeckte hohlenbewohnende Herpobdellide.—Zoologischer Anzeiger 42:77-80.
- Klemm, D. J. 1972. The leeches (Annelida: Hirudinea) of North America. Identification manual Number 8, Biota of freshwater ecosystems. Water Pollution Control Research Series 18050 ELD05/72. U.S. Environmental Protection Agency, Washington, D.C., 54 pp.
- . 1977. A review of the leeches (Annelida: Hirudinea) in the Great Lakes Regions.—Michigan Academician 9(4):397-418.
- . 1982. Leeches (Annelida: Hirudinea) of North America. U. S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268, EPA-600/3-82-025, 177 pp.
- . 1985. Freshwater leeches (Annelida: Hirudinea). Pp. 70-173 in D.J. Klemm, ed., A guide to the freshwater Annelida (Polychaeta, naidd and tubificid Oligochaeta, and Hirudinea) of North America. Kindall/Hunt Publication Company, Dubuque, Iowa, 198 pp.
- . 1990. Hirudinea. Pp. 398-415 in B. L. Peckarsky, P. R. Fraissinet, M. A. Penton, & D. J. Conklin, Jr., eds., Freshwater macroinvertebrates of northeastern North America. Cornell University Press, Ithaca, New York, 442 pp.
- Kobakhidze, D. N. 1958. [New subspecies of cave leech (Hirudinea: Herpobdellae) from Georgia, SSR.]—Soobshcheni Akademii nauk Gruzinsk SSR 21(5):591-592.
- Kosel, V. 1980. Our little known leeches 2: *Trocheta bykowskii*.—Ziva 28(4):141.
- Lasca, C. 1989. Paleogeographical and hydrogeolog-

- ical hypothesis regarding the origin of a peculiar cave fauna.—*Miscellanea speologica Romanica* 1:13–18.
- , R. Popa, S. M. Sarbu, L. Vlasceanu, & S. Prodan. 1993. La Grotte de Movile, une faune hors du temps.—*La Recherche* 258:1092–1098.
- Linnaeus, C. 1758. Hirudinea. Pp. 648–651 in *Systema Naturae per Regna Tria Naturae, Secundum Classes, Ordines, Genera, Species, Cum Characteribus, Differentiis, Synonymis, Locis*. Tomus I. 10 Editiodesima, Reformata. Facsimile edition, British Museum (Natural History), 1939, 824 pp.
- Lukin, E. I. 1955. Leech fauna of the Amur basin.—*Zoologicheskii Zhurnal* 34(2):279–285.
- . 1976. Leeches of fresh and salt water reservoirs. Fauna SSSR, No. 109, Part 1, New Series, Academy Science SSSR, Leningrad, Soviet Union. 467 pp.
- Mann, K. H. 1961. Leeches (Hirudinea): their structure, physiology, ecology and embryology. Pergamon, New York, 201 pp.
- Manoleli, D. 1972. A new species of leech *Limnatis bacescui* sp. nov. (Hirudinoidea: Hirudiniidae).—*Revue Roumaine de Biologie Series Zoologie* 17(4):237–239.
- . 1974. Contributions to the knowledge of the Hirudinea from the eastern Romanian Plain and from the Mounts of Vrancea.—*Travaux Museum d'Historie naturelle "Grigore Antipa"* 14: 79–83.
- Mathers, C. K. 1954. *Haemopsis kingi*, new species (Annelida, Hirudinea).—*American Midland Naturalist* 52:460–468.
- . 1963. *Haemopsis latero-maculatum*, new species (Annelida: Hirudinea).—*American Midland Naturalist* 70:168–174.
- Miller, J. A. 1929. The leeches of Ohio. Ohio State University, Franz Theodore Stone Lab. Contribution No. 2., Ohio State University, Columbus, Ohio, 38 pp.
- Moore, J. P. 1912. Classification of the leeches of Minnesota. Pp. 63–150, in *The leeches of Minnesota*.—*Geological Natural History Survey of Minnesota, Zoological Series*. No. 5, Pt. 3.
- . 1938. Leeches (Hirudinea) from Yucatan caves.—*Carnegie Institute Washington Number* 491, pp. 67–70.
- Moquin-Tandon, A. 1826. Monographie de la famille des hirudinees, Montpllier, pp. 1–152.
- Muller, O. F. 1774. Vermium terrestrium et fluviatilium, seu animalium infusorium, helminthico-rum et testaceorum, non marinorum, succincta historica. Havniae et Lipsiae Pars I, pp. 1–72, spec. p. 39.
- Peck, S. B. 1988. A review of the cave fauna of Canada, and the composition and ecology of the invertebrate fauna of caves and mines in Ontario.—*Canadian Journal of Zoology* 66:1197–1213.
- Richardson, L. R. 1969. A contribution to the systematics of the hirudinid leeches with description of new families, genera and species.—*Acta Zoologica Academiae Scientiarum Hungaricae* 15(1–2):97–149.
- . 1971. A new species from Mexico of the Nearctic genus *Percymoorensis*, and remarks on the family Haemopidae (Hirudinoidea).—*Canadian Journal of Zoology* 49(8):1095–1103.
- . 1974. A new troglitic quadrannulate land-leech from Papua (Hirudinoidea: Haemadipsidae s. l.).—*Proceedings of the Linnaean Society of New South Wales* 99:57–68.
- Ruckert, F. 1985. Egel aus den Laevante-Länder (Cli-tellata: Hirudinea), *Senckenbergiana Biologie* 66:135–152.
- Sarbu, S. M., & T. C. Kane. 1995. A subterranean chemoautotrophically based ecosystem.—*National speleological Society Bulletin* 57:91–98.
- , ———, & B. K. Kinkle. 1996. A chemoautotrophically based groundwater ecosystem.—*Science* 272:1953–1955.
- Savigny, J. C. 1822. Systeme des Annelides. Pp. 105–120 in *Systeme de diverses classes d'anemiarix sans Vertebres* Paris 1(3).
- Sawyer, R. T. 1986a. Leech biology and behavior; Anatomy, physiology, and behavior, Volume I, Oxford University Press, Oxford. 417 pp.
- . 1986b. Leech biology and behavior; Anatomy, feeding biology, ecology, and systematics, Volume II, Oxford University Press, Oxford, Pp. 419–793.
- . 1986c. Leech Biology and behavior; Bibliography, Volume III, Oxford University Press, Oxford, Pp. 799–1065.
- , & R. M. Shelley. 1976. New records and species of leeches (Annelida: Hirudinea) from North and South Carolina.—*Journal of Natural History* 10:65–97.
- Say, T. 1824. On *Hirudo parasitica*, *lateralis*, *mar-morata*, and *decora*, on the voyage of Major Long. Pp. 266–268 in W. H. Keating, Narrative of the expedition to the source of St. Peters River, Lake Winnipeck, Lake of the Woods in 1823 under Stephen H. Long, 2 vols., Philadelphia. Appendix of natural history. *Zoology* 2:253; Vermes 2.
- Scriban, I. A., & H. Autrum. 1934. Ordnung der Cli-tellata: Hirudinea, Egel. Pp. 119–352, in W. Kunkenthal, & T. Krumbach, *Handbuch der Zoologie* 2(8).
- Sket, B. 1986. Hirudinea. in *Stygo fauna Mundi*, L. Botosaneanu, ed., E. J. Brill, Leiden, Amsterdam. pp. 250–253.
- Sladeczek, V., & V. Kosel. Indicator value of freshwater leeches (Hirudinea) with a key to the determi-

- nation of European species.—*Acta Hydrochimica et Hydrobiologica* 12(5):451–461.
- Soos, A. 1966. Identification key to the leech (Hirudinoidea) genera of the world, with a catalogue of the species. 3. Family: Erpobdellidae.—*Acta Zoologica Academiae Scientiarum Hungaricae* 12(3/4):317–407.
- . 1969. Identification key to the leech (Hirudinoidea) genera of the world, with a catalogue of the species: 5. Family: Hirudinidae.—*Acta Zoologica Academiae Scientiarum Hungaricae* 15(1/2):151–201.
- . 1970. A zoogeographical sketch of the freshwater and terrestrial leeches (Hirudinoidea).—*Opuscula Zoologica (Budapest)* 10(2):313–324.
- Turquin, M. J. 1994. Un cas de transition démographique dans le milieu souterrain.—*Verhandlungen der Internationalen Vereinigung für Theoretische und Angewandte Limnologie* 22(3): 1751–1754.
- Verrill, A. E. 1874. Synopsis of the North American fresh water leeches.—*Report of the Commission for the U.S. Fish and Fisheries 1872/73*: 666–689.
- Weiss, I., & S. M. Sarbu. 1994. Die Höhlenspinne *Agraecina cristiani* (Georgescu, 1989) n. comb. (Arachnida, Araneae, Lioeraniidae).—*Verhandlungen des Naturwissenschaftlichen Vereins zu Hamburg* 34:249–257.